A STUDY OF RECREATIONAL BOATING PUBLIC INTERVENTIONS, REGULATIONS AND ACCIDENTS UTILIZING FEDERAL AND STATE DATA

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Abstract

Existing research on public regulation for recreational boating focuses on the use of personal flotation devices or drunkenness while boating. This study takes a different approach by evaluating a combination of public data available from the State of Florida on the maritime domain, public interventions such as aids to navigation and public regulations like boating safety education. These data are examined with boating accident data to determine if a relationship exists at both a county level and at the accident-level. This study fills a prominent void in scholarly literature regarding boating safety public regulation and its relationship to boating accidents. The result of the analysis was surprising in that public service actions such as the placement of Aids to Navigation like buoys and channel markers and the issuance of boater safety cards as a result of education completion which are designed to reduce the boating accident rate seemed to have a reverse effect at the county level. Further, when evaluated at the accident level, age, experience and education of a boat operator had a noticeable effect on the probability of injuries and fatalities in boating accidents. Findings from this research have a potential to be incorporated into state level risk-based decision making, actuarial modeling and budgeting on public regulation programs.

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1.0 Introduction

In today's connected society, Americans can participate almost freely in recreational boating and water sports with virtually no experience. Online platforms and waterfront businesses make renting a boat virtually seamless to any person with little vetting on experience or background. This leads to inexperienced boaters plying the nation's waterways in a machine they are not used to operating in an environment that is unlike driving a vehicle on the road. This is similar to the way that any person can utilize their smartphone to rent a bicycle or electric scooter and ride it in a city with which they are unfamiliar. Operating a boat on the water requires a knowledge of nautical rules and operating procedures. A boater safety course taken before engaging in recreational boating provides a user with a basic background needed to navigate the water with some states requiring a boater safety course. All these transportation modes require sensible regulation in order to ensure the safety of users that choose to participate. Therefore, it is important that a foundation of research be built to examine public regulation and interventions related to boating safety, utilizing actual recreational boating data. Previous studies on public regulation and its effects on recreational boating accidents aggregated the data of all 50 states and applied the effects of broad demographics and public regulations to boating accident variables. This study utilizes specific accident-level data and waterway-specific variables to look at factors that may cause boating accidents.

The Federal Government shares in the responsibility of boating safety with states by ensuring waterways facilitate commerce, regulating the industry behind recreational boating, making regulations on boating safety and by enforcing laws alongside state law enforcement. States can impose regulations such as mandatory boating safety courses, proper registration and titling of recreational boats, and the creation of safety zones on waterways alongside Federal partners. Localities like cities and counties patrol waterways, enforce laws and regulate waterfront businesses and access points. Recreational boating regulation very much involves local governance as much as it does Federal governance. A very similar model is that of seatbelt laws or alcohol consumption laws and the Interstate Highway System.

This research expands on existing studies by examining new data that has become available including geospatial information data on aids to navigation and boating zones and boater access sites at the county-level for the State of Florida. Florida was chosen for this study due to its large recreational boating population and higher number of boating accidents compared to other states. This research also evaluates a year of Florida boat accident-level fatality and injury data to determine what variables increased or decreased the chance of injury or death. The public intervention that is overarching in both studies is boater education at the county level analysis and then at the accident-level analysis. In Florida, a boater must obtain a boater safety identification card by completing a boating safety course if they were born after January 1, 1988. The results suggest that any boater would benefit from boating education as data showed education was a factor that affected the probability of a fatality in a boating accident.

The use of ordinary least squares linear regression and a logistic regression were utilized in this research. The first analysis utilizes linear regression to determine the variables that were more likely to have a relationship with boating accidents in a Florida county. This county-level model combines data on population, safety intervention and regulations such as aids to navigation, boating safety zones, boater safety identification cards, boater access and waterways mileage data.

Some of the expectations this research should show are that public safety interventions such as aids to navigation, safety zones, boater safety card issuances resulting from completion of boater safety education should register a decrease in the number of boating safety accidents in a specific county. Evaluating a specific county's boating safety and waterways profiles should yield a direct relationship. However, there are certain nuisances related to the data. For instance, boater safety cards are registered to the address they put on file so therefore this intervention may not be a truly accurate representation of a county and how safe their boaters actually are. Furthermore, boaters can transit to different counties to operate their boats.

Expectations from looking at accident-level data are that there will be certain variables that strongly contribute to boating accidents that result in injury or in a fatality. It could be postulated that inclement weather, operator inexperience, the lack of boating education, and age have an increased likelihood on accidents resulting in injury or a fatality. Evaluating accident-level data can have potential in segmenting the data into specific types of accidents, such as accidents that involved a person falling overboard, or looking specifically at collisions between boats or accidents involving solely personal watercraft.

2.0 Literature Review and Theoretical Framework

Research in the recreational boating safety regulatory space is mostly uncharted. In Willcox-Pedgeon et al, they state that few studies have explored the effect of regulations on recreational boating safety.[1] Willcox-Pedgeon examined the three-year average crude rate immediately following the introduction of a licensing requirement in the State of Western Australia and found that the crude rate had halved.[2] However, they could not postulate that this decrease was due to increased boating knowledge through the part of a licensing program.[3] Virk and Pikora conducted survey-based research during the initial roll out of the licensing program in Western Australia and found that a majority of respondents had changed their on-board behavior on recreational boats as a result of obtaining a boating license.[4] Wang studied the effects of state regulations on boating accidents and fatalities utilizing data from 1990 to 1994 to examine whether public laws and demographics such as income, mandatory education, minimum operating age, personal floatation devices, state beer tax and implied consent had an effect on the accident and fatality rate in boating. Wang found several statistically significant variables including a minimum operator age and boating education in public school to have an impact on lower rates in accidents and fatalities.[5] Gabe and Hite examined various public safety education and interventions such as boater education programs and water patrol officers to build a simulation on modeling a minimum that states should meet in order to reduce accidents. Their simulation concluded that 1.5 water patrol officers per 1,000

[1] Willcox-Pidgeon, Stacey, Amy Peden, Richard Franklin, and Justin Scarr. "Boating-related drowning in Australia: Epidemiology, risk factors and the regulatory environment." Journal of Safety Research, 118

[2] Crude Rate: In the Willcox-Pidgeon study, crude rates of death from boating drowning rates were calculated per 100,000 registered recreational boats by state/territory and financial year where data were available, as a proxy for exposure.

[3] Willcox-Pidgeon, et al., *Journal of Safety Research*, 123

[4] Virk, Amanpreet, and Terri Pikora. "The Recreational Skippers Ticket and Its Influence on Boater Behavior." International Journal of Aquatic Research and Education, 2010, 180.

[5] Wang, Weiren. "The Effects of State Regulations on Boating Accidents and Fatalities." Applied Economic Letters, 2000, 377

boaters would prevent approximately 2,300 boating accidents in 33 states.[6] They also concluded that 20 hours of instruction would prevent 170 accidents in 39 states.[7] Finally, several Sea Grant recreational boating surveys were conducted for several Florida counties. In the survey conducted for Sarasota County, 86.8% of respondents to their survey indicated a need for more boater education on etiquette, safety, skills and regulation.[8]

This research leveraged the U.S. Coast Guard's Boating Accident Report Database (BARD), a database that serves as a receptacle for boating accident report data submitted by 56 states and territories.[9] Under Federal Regulations, a Boating Accident Report must be filed under certain circumstances per 46 United States Code 6102.[10] BARD has been utilized by different scholars to study boating safety. BARD data was utilized by Ryan, Nathanson, Baird and Wheelhouse to calculate a 1.19 per million fatality rate for recreational sailboat accidents, which is similar to the fatality rates associated with alpine skiing and snowboarding. Similarly, McKnight, Becker, Pettit and McKnight examined at all types of recreational vessels in BARD and found that the extent of errors in boating accidents vary significantly among different boat types. The authors identified that existing boating safety courses only generalize safety principles without taking into account boat type. This analysis also changed the types of boating safety errors that BARD tracks, allowing for the Coast Guard to consider them in

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[6] Gabe, Todd, and Diane Hite. "The Effects of Boating Safety Regulations." Coastal Management, 2003, 253

[7] Ibid., 253

[8] Sidman, Charles, Robert Swett, Tim Fik, Susan Fann, and Bill Sargent. *A Recreational Boating Characterization of Sarasota County.* Gainesville, FL: Florida Sea Grant College Program, 66

[9] U.S. Department of Homeland Security. Boating Accident Report Database . Privacy Impact Assessment, Washington, DC: U.S. Department of Homeland Security, 2009, 2

[10] Ibid., 2

prevention measures. Scholars in epidemiology, Lasala, et al., analyzed BARD to determine accidents as a result of carbon monoxide poisoning on boats and found no significant trend in carbon monoxide poisoning among nationwide data. Viauroux and Gungor utilized BARD to create a simulation that would predict the effect of more stringent lifejacket regulations. They postulate that 1,721 out of 3,047 of boating fatalities from 2008 to 2011 could have been prevented if mandatory lifejacket laws were in effect.

Public access to the water plays a crucial role in defining the boater culture for the area. Glover, Lane and Wang conducted a survey on alcohol consumption at public and private marinas in Beaufort County, North Carolina. Their survey-based research focused at marinas where boaters were preparing to go out on the water with their recreational boats. Their results found a stronger prevalence of alcohol use at private marinas versus public marinas. This finding suggests that laws prohibiting alcohol use in boating may only be effective at public boat accesses.[11] Boating access studies have also been initiated by multiple states including Florida and Virginia in order to better maintain data on boater access and on recreational boating economic impact. Virginia conducted a boater access study and found that boating access sites are more than just a "boat ramp." Boating access sites are analogous to trailhead parking sites and fulfills water access for a personal interest.[12] The State of Florida initiated a study to conduct an inventory of private, public and residential public access points to quantify the economic impact of recreational boating and to forecast future demand for boating facilities and access capacity. Florida's plan examined different variables at existing boater access facilities to

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[11] Glover, Elbert, Susan Lane, and Min Qi Wang. "Relationship of Alcohol Consumption and Recreational Boating in Beaufort County, North Carolina." *Journal of Drug Education*, 1995, 156

[12] Virginia Department of Game and Inland Fisheries. Virginia Department of Game and Inland Fisheries: Boating Access Site and Facility Management Plan. Virginia Department of Game and Inland Fisheries, 2019, 7

determine what characteristics future boater access should have. The study found that boating access areas that have ample parking and an adequate number of lanes available for launch made an access site more attractive to boaters. This study assumed that a boater will choose a combination of a launch ramp and water destination among many possible alternatives each time he wants to make a trip.[13] Since an accident could occur anytime from when the boat leaves the access point to the time the boater returns to the boater access, access points are a key to examining boating accidents.

Federal and State entities have multiple tools to regulate waterways and boat traffic. Short range aids to navigation such as buoys and beacons/channel markers are put in place by the U.S. Coast Guard and are used by vessels to determine their position, follow a safe course and avoid dangers and obstructions.[14] The overall Aids to Navigation Constellation in a waterway indicates the ship navigation safety level in the channel.[15] In the Florida Boater Access study survey, the results yielded that boaters were not likely to choose areas with navigation aids as an intended water destination. Boating Safety Zones regulate traffic by either imposing a speed restriction or no wake zone around an area with dense traffic, residential docks or around bridges and other structures. Swett, et al. evaluated boating safety risk in Florida's Intracoastal Waterways and devised a spatial decision support system to supplement Florida's existing risk analysis method in devising boating safety zones. Florida approves regulatory markers to demarcate a safety

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[13] Florida Fish and Wildlife Conservation Commission. "The Florida Boating Access Facilities Inventory and Economic Study." Lee County, FL, 2009., 153
[14] U.S. Coast Guard. Overview of the U.S. Coast Guard Short Range Aids to Navigation Mission. Springfield, VA: John A. Volpa National Transportation Systems Center, 1994, 1
[15] Chen, T, J Chen, C Shi, and D Jia. "Real-Time Risk Assessment for Aids to Navigation Using Fuzzy-FSA on Three-Dimensional Simulation System." The International Journal on Marine Navigation and Safety at Sea Transportation, 197

zone that are of valid vessel traffic safety or public safety purpose.[16] The risk factors that validate the need for regulation include injuries/fatalities, vessel collision and damage to maritime property.[17] Swett utilized a spatial decision support system coupled with a public input process to determine the adoption of two new boating safety rules for Palm Beach and Martin counties in specific locations identified to have elevated risk levels indicated by a density of occurrence.[18]

3.0 Data and Methods

Data on the maritime domain is maintained by Federal and State Governments for different purposes. Recreational boat data is difficult to track as they are not subject to certain sensor equipment carriage regulations like cargo vessels.[19] User survey data is the most prevalent use of tracking recreational boating, followed by some sensor data and through data collected at some locks and bridges. However, as recreational boaters utilize public facilities, there are many State governments that track recreational boating data for taxation and for urban planning purposes. It was important for this study to select data from a recreational boating environment considered to be accurate and robust. The State of Florida has a strong recreational boating culture with the greatest number of registered recreational boats behind Minnesota and California.[20] Its primary law enforcement agency on the water, the Florida Fish and Wildlife Conservation Commission (FWC), Division of Law Enforcement manages waterways, enforces recreational boating laws and regulations and investigates boating accidents. Data obtained for this analysis were

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[16] Swett, Robert, Charles Sidman, Timothy Fik, Russell Watkins, and Paul Ouellette. "Evaluating Boating Safety Risk in Intracoastal Waterways." Coastal Management, 2011, 617
[17] Ibid., 617
[18] Ibid., 623
[19] Otherwise known as the Automatic Identification System (AIS)
[20] U.S. Coast Guard. "2018 Boating Recreational Statistics." Washington, DC, 2018, 71

primarily collected by FWC and include geospatial information system (GIS) data on boat ramp and marinas as well as data on boater safety identification card issuances. The Coast Guard collects Boating Accident Reports from the State and normalizes it in the annual Boating Accident Report Database (BARD). The Coast Guard also maintains Aids to Navigation data which contains coordinate data for each aid. Population data was collected by the Florida Office of Economic & Demographic Research (EDR). Table 1 details the dataset, sources and descriptions of these data.

Table 1: Datasets, sources, and description

Dataset	Source	Description
Boating Accident Statistical Reports	FWC	Aggregated Statistics by County on number of registered boaters, accidents, fatalities and injuries and Boater Safety Identification Card registrations
Boating Accident Report Database	USCG	Accident-level accident data containing data on environmental factors, time, operator characteristics
Population Data	EDR	Population data for each County in Florida based off Census figures
FWC Florida Boat Ramp Inventory	FWC	GIS data from the Florida Boating Access Facilities Inventory and Economic Study
Marinas Florida	FWC	GIS data from the Florida Boating Access Facilities Inventory and Economic Study
Aids to Navigation	USCG	GIS data on Aids to Navigations (buoys and beacons) from the United States Coast Guard
Boater Safety Identification Cards	FWC	Data from FWC on “Bobber Cards” issued in 2018. Specifically requested from FWC.
State Boating Safety Zones, Florida	FWC	GIS data on FWC Boating Restricted Areas as described in Florida Administrative Code Chapter 68D-24.

Data from each of the above sources were aggregated at the county level. With regards to the Aids to Navigation data, coordinate data first had to be input into ESRI ArcGIS Online and spatial analysis conducted in order to form aggregated statistics by county. Utilizing publicly available polygon layers on Florida counties, an aggregated dataset of Aids to Navigation by county was formed. Data from the Boating Accident Report Database contains accident-level data. While the data are normalized and accessible through Microsoft Access, some data cleaning was needed to make it machine readable for linear and logistic regression in RStudio and Stata. Dummy variables were introduced for some variables such as aggregating operator experience, vessel type and operator education into interval level data.

In 2018, there were 609 boating accidents involving 869 vessels in Florida that met the threshold of inclusion into the nationwide Boating Accident Report Database (BARD).[21] Table 2 highlights the top 10 Florida counties and their boating casualty rates, along with demographic data. Of these accidents, there were 57 fatalities and 297 injuries totaling $7.26 million dollars in documented damage to boats and property. Each county suffered an average 11 accidents in 2018, with the median being 5 accidents and the standard deviation being 15 accidents. Monroe County in the Florida Keys had the highest number of accidents at 75, while Hillsborough County had the highest number of boating fatalities at 12. Both Monroe and Miami-Dade counties, respectively, had 28 injuries related to boating accidents. Sarasota County saw the highest dollar in damage at $1.5 million.

[21] Boating Accidents included in BARD must meet criteria per 33 CFR 173: A person dies, a person disappears from the vessel under circumstances that indicate death or injury, A person is injured and requires medical treatment beyond first aid. Damage to Vessel or other property totals $2,000 or more or there is a complete loss of the vessel.

Table 2: Top 10 Florida Counties – Boating Casualty and Participation Figures (2018)

County	Accidents	Injuries	Total Population	Registered Recreational Boats	Length of Waterways (miles)
MONROE	75	28	76,212	26,166	689
MIAMI-DADE	67	28	2,812,130	65,142	237
PINELLAS	40	16	978,045	49,377	205
PALM BEACH	36	18	1,447,857	35,191	185
HILLSBOROUGH	32	20	1,444,870	40,134	222
LEE	31	9	735,148	46,690	223
BROWARD	25	6	1,919,644	44,018	206
SARASOTA	24	9	426,275	22,511	69
VOLUSIA	21	16	538,763	27,536	125
COLLIER	21	13	376,706	21,653	137

Sources: USCG, Florida Wildlife Commission, Florida Census

In 2010, a new law was passed by Florida requiring all boaters born after January 1, 1988 to complete a one-time boater safety course and carry a boater safety identification card as proof of boater education completion.[22] The State of Florida has approved both in person and online courses in order to fulfill the requirement for the boater safety identification card. Table 3 details the demographics of boaters in Florida and accident data from 2008 to 2018. Since the enactment of that regulation in 2010, the number of recreational boaters increased by approximately 2%. During that same period of eight years, reportable accidents have followed an upward trend while the number of fatalities and injuries have remained steady.

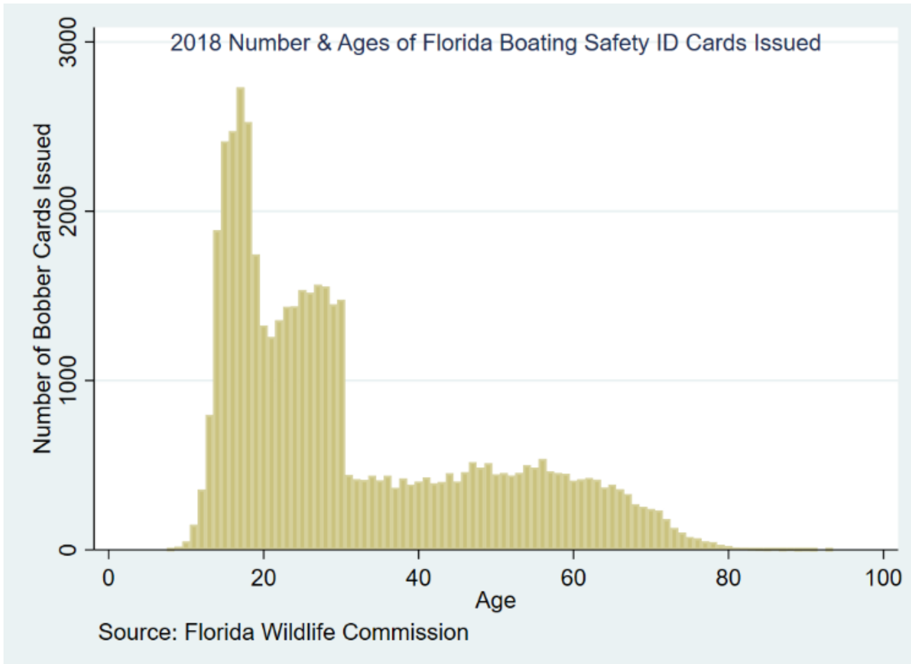
[22] Croft, D. Scott. Captiva Sanibel. December 29, 2010. http://sanibel-captiva-islander.com/page/content.detail/id/509896/Florida-boaters-can-take-free-boating-safety-course-at-home.html?nav=5053 (accessed April 2020, 26).

Table 3: Florida Recreational Vessels Accident Statistics (2008 – 2018)

Year	Recreational Vessels	Total Vessels	Reportable Accidents	Fatalities	Injuries
2008	973,836	1,010,359	659	54	383
2009	949,030	982,470	620	65	426
2010	901,737	941,589	668	79	389
2011	889,895	922,491	742	67	431
2012	870,031	901,969	704	55	386
2013	870,749	896,632	736	62	420
2014	867,463	899,635	634	73	365
2015	883,332	915,713	737	55	438
2016	899,235	931,450	714	67	421
2017	912,392	944,162	766	67	437
2018	919,302	950,740	628	59	307

Data from 2018 was obtained from FWC on Florida Boating Safety ID Card issuance, sorted by age and county. In 2018, approximately 48,000 cards were issued. The below graph shows the distribution of the issued cards for 2018. The mean age of card issuance was 31.8 years of age, while the median age was 26 and the mode of card issuance was 17 years old. This indicates a positive skew of the data and is observed in Figure 1. Figure 1 also illustrates a significant drop-off of card issuances after the age of 30. The maximum recorded age for card issuance was 118, followed by 112 which were eliminated as outliers. The next realistic maximum age was 93. The standard deviation of the issued cards ages was 16.9 years and therefore 95% of the issued cards ranged between the minimum of 8 years of age and 65 years of age.

Figure 1 – 2018 Number & Ages of Florida Boating Safety ID Cards Issued



Finally, Table 4 combines all access and mitigation variables from the different counties together. Of note, this table is made up of five separate data sources. While this table is sorted by the number of accidents in descending order, there is no discernible trend that can be derived utilizing summary statistics. However, Monroe County located in the Florida Keys possesses a high number of access points to the water, no safety zones and a low number of boater safety card holders. This could be indicative of the culture in the Florida Keys, where boaters are more transient than residential. The Keys also has no safety zones as it is in relatively open waters, away from residential homes and the Intracoastal Waterway system. Given these variables, Monroe County could be considered an outlier.

Table 4: Top 10 Florida Counties for Boating Casualties – Access and Mitigation Variables

County	Accidents	Access Variables: Boat Ramps	Access Variables: Marinas	Mitigation Variables: Aids to Navigation	Mitigation Variables: Safety Zones	Mitigation Variables: 2018 Issued Boater Safety Cards
MONROE	75	50	378	470	0	599
MIAMI-DADE	67	38	185	268	7	3671
PINELLAS	40	53	186	374	9	2034
PALM BEACH	36	50	164	226	16	2593
HILLSBOROUGH	32	37	41	234	0	2302
LEE	31	73	156	201	1	1545
BROWARD	25	49	286	81	18	2216
SARASOTA	24	26	61	158	6	1014
VOLUSIA	21	79	76	289	16	889
COLLIER	21	27	105	154	0	861

4.0 Results

Six models were created in order to assess the impact of the predictors. The first four models utilize a multivariate linear regression with the number of boating accidents in a county as the dependent variable. The variables are listed below:

(1) Model 1 (Demographic Data): Population of the County, Number of Registered Recreational boats in the county

(2) Model 2 (Demographic Data and Access Variables): Population of the County, Number of Registered Recreational boats in the county, boat ramps, marinas and waterway length

(3) Model 3 (Safety Variables only): Number of Boater Safety Cards issued in 2018, Aids to Navigation/Channel Markers and Safety Zones in the County

(4) Model 4: All Variables Above

The last two models utilize logistic regression to model accident-level data from each vessel involved in the accident to determine causal factors that may have a relationship with both injuries and fatalities. For each model, the result is a binary variable: 0 for no injury or no death, 1 if injury or death occurred in the accident. The variables reviewed in these models include:

(1) Operator Variables: Age of the Operator, boating education (yes/no), Experience of Operator (Under 10 hours, 10 – 100 hours, 101 – 500 hours)

(2) Vessel Variables: Power-Driven vessel, rental vessel

(3) Date/Time Variables: Weekend (yes/no), night (yes/no)

(4) Environmental Variables: Weather, water condition, wind condition

The results show that boater access via marinas increased the number of boating accidents in a county. It also showed that safety zones had a negative correlation on the number of accidents, meaning safety zones decreased the amount of accidents. However, the surprising result showed that both aids to navigation and boater safety identification cards have a positive relationship to boating accidents. This is an important point in that it may prove difficult to justify a government program meant to decrease accident rates when in fact, the relationship is opposite of the argument. Further research is needed to form the qualitative and quantitative theory behind these safety measures intended to improve the public boating experience.

The second model utilizes logistic regression to examine fatalities and injury in boating accidents and the variables that could contribute to an accident. This model utilized accident-level data on all vessels involved in an accident, keeping in mind that there could be multiple vessels involved in a boating accident. For injuries, the model found that age of the operator, whether an accident happened during the day or night, whether the vessel was power-driven and whether the vessel was rented to be statistically significant. In evaluating fatalities, the model found none of the environmental or time variables to be statistically significant. However, the model did find an inverse relationship between both operator education and experience in reducing the probability of a fatality. In other words, the model indicated that boaters with higher levels of education or experience have a lower probability of being involved in a fatal accident.

4.1 Public Interventions and Regulations in Boating Accidents

This ordinary-least squares multivariate linear regression looks at Federal and State data at the county-level. The goal of this model is to explore whether there is an effect on public safety regulations and interventions on the waterway, controlling for the access variables that enable public access to the water along with demographic data on boater registrations and population. The resultant model displayed in Table 5 then examines all variables together. Models 1 and 2 examined population and boater access variables. Both found the population variable to be statistically significant at the 95% confidence level. In Model 1, the data suggests that for every 1,000 registered boaters in a county, one boating accident occurred. In Model 2, approximately 3,191 registered boaters in a county accounted for one boating accident. Model 2 also accounts for public access points to the water. In this model, an increase of approximately 18 marinas accounted for one additional accident while 15 miles of waterway accounted for an accident.

Model 3 looks at the safety components of a waterway: Boater Safety Education Cards Issued in 2018, Aids to Navigation/Channel Markers and State Safety Zones. There were no statistically significant variables. Each of these variables was expected to have a negative coefficient. However, only the safety zones variable produced a negative coefficient while the rest produced a positive coefficient. The model suggests that one safety zone decreased annual boating accidents by three. This may also indicate that safety variables need to be looked at in conjunction with the population being studied.

Model 4 accounts for all the aforementioned variables and finds a statistically significant relationship between boating accidents and marinas, registered boating safety cards, aids to navigation/channel markers and safety zones. The expected effect of a boater safety cards and aids to navigation/channel markers should be negative, but in this model the coefficients suggest the opposite. This last model suggests a boat accident for every ten marinas and a reduction of one accident for every safety zone.

Table 5 - Multivariate Regression Results - Public Interventions in Boating Accidents				
Variables	Model 1 - Population Figures only	Model 2 - Population and Access Variables	Model 3 - Safety Variables	Model 4 - All Variables
Constant	-3.0188030 (.0001790)	-3.1619800 (1.371744)	-0.6803314 (1.248054)	-1.0155930 (1.390164)
Registered Recreational Boats	0.0010029* (.0001790)	0.0003133* (0.0001368)		-0.0002759 (0.0001878)
General Population	-0.0000054 (.0000048)	0.0000030 (0.0000030)		0.0000028 (0.00000385)
Boat Ramps		-0.0285042 (0.0351979)		0.0168120 (0.0336459)
Marinas		0.0555507* (0.0222480)		0.0965897* (0.0251121)
Waterway Length		0.0666706* (0.0135960)		0.0220814 (0.0190054)
Registered Boater Safety Cards in 2018			0.0085372 (.010694)	0.0085542* (0.0032726)
Aids to Navigation/Channel Markers			0.0853080* (.010694)	0.0443223* (0.0143916)
Safety Zones			-0.3133175* (.282394)	-0.5571046* (0.2540429)
r^2	.6148	.8818	.7851	.9119
Adjusted r^2	.6010	.8706	.7734	.8978
n	59	59	59	59
*Statistically Significant at .05				

Some of these results were surprising. Aids to Navigation and Issued Boater Safety Identification Cards showed a positive relationship to boating accidents in a county. This presents a challenge in that there may not be a logical and quantifiable result in an intervention, especially when the expected result is a negative relationship. The issue is these interventions are funded by taxes at the state and Federal level. A budget proposal at the county, state or Federal level utilizes performance plans and measures to determine the effectiveness of programs. However, safety regulations and interventions that do not produce a decrease in the number accidents may need more scrutiny.

4.2 Contributing Factors to injuries in Florida recreational boating accidents

The next two models seek to identify those variables that lead to injury or death in a boating accident. Insight derived from these two models could be incorporated into risk-based decision-making processes when implementing a public safety intervention on a waterway. This analysis also evaluates whether an operator involved in an accident had any boater education.[23] Results from these models could potentially help to confirm the positive effect that boater safety identification cards had in the previous model in boating accidents. As explained previous in Figure 1, the issuance of Boater Safety Identification Cards decreases dramatically after age 30. Therefore, the following hypothesis is proposed for both models to look at the effect of age on injuries and fatalities in boating accidents:

> Null Hypothesis: There is no relationship between the age of an operator and injury in a boating accident
>
> Alternative Hypothesis: There is a positive relationship between the age of an operator and injury in a boating accident.

This logistic regression model explained in Table 6 takes all boating accidents that occurred in the State of Florida during 2018 and maps it with data from each vessel that was in the accident. There are instances where boating accidents involve multiple vessels and incidents where a single boater has a boating accident. Data is collected by FWC on the type of vessel, the time and environmental factors, the operator's age,

[23] The data for each accident lists the type of education an operator had, but did not state whether the operator had a Boater Safety Identification Card.

education and experience. These variables are then regressed on the dependent variable which is injury in a boating accident.

Table 6 – Logistic Regression Output for Injuries from 2018 Florida Boat Accidents

Variable	Coefficient	Standard Error	Exponent	Odds Ratio	Standard Error	p-value	Significant
Constant	-2.040	0.910	4.160	0.130	0.118	0.025	
Age	-0.021	0.006	0.000	0.980	0.006	0.000	Yes
Day	0.522	0.248	0.273	1.686	0.419	0.035	Yes
Power-Driven Vessel	0.747	0.355	0.558	2.110	0.749	0.035	Yes
Rental Vessel	0.701	0.260	0.491	2.015	0.524	0.007	Yes
Weekend	-0.070	0.179	0.005	0.933	0.167	0.697	
Operator Education	-0.115	0.209	0.013	0.891	0.186	0.582	
Weather							
Clear	0.609	0.507	0.371	1.839	0.933	0.230	
Cloudy	0.364	0.482	0.132	1.439	0.693	0.450	
Rain	-0.064	0.437	0.004	0.938	0.410	0.883	
Hazy	0.850	0.924	0.723	2.340	2.162	0.357	
Operator Experience							
< 10 hours	0.377	0.436	0.142	1.458	0.636	0.388	
10 - 100 hours	-0.003	0.382	0.000	0.997	0.381	0.993	
101 - 500 hours	0.311	0.365	0.097	1.364	0.498	0.395	
Water Condition							
Choppy	0.406	0.225	0.165	1.501	0.338	0.071	
Rough	0.299	0.366	0.089	1.349	0.494	0.414	
Very Rough	2.242	1.223	5.027	9.414	11.509	0.067	
Wind Condition							
Light	0.575	0.521	0.330	1.776	0.926	0.270	
Moderate	0.326	0.537	0.106	1.385	0.743	0.544	
Strong	-0.174	0.610	0.030	0.841	0.513	0.776	
Storm	0.000	0.000	0.000	1.000	0.000		

Log-Likelihood = -398.4102 | n = 643| df = 19 | LR chi-square = 59.72 | Pseudo R^2 = .0697

The four variables that were statistically significant at the 95% confidence level were age, accident occurring during the day or night, power-driven vessel (as opposed to a self-propelled vessel), and a rental vessel. In evaluating the proposed hypothesis (1), the null hypothesis can be rejected and alternative hypothesis be accepted in that there is a relationship in operator age and the chance of injury occurring since the p-value of the *age* variable is less than .05. A boating accident with injury is 1.686 times more likely to happen during the day than at night. This could be attributed to a decreased amount of boat traffic at night as recreational boaters may feel less comfortable navigating waterways at night. A power-driven vessel is about twice as likely to be engaged in an accident than a non-propelled vessel.[24] It is a reasonable assumption that a power-driven vessel is usually steered by an operator utilizing navigation systems and as a result, there is an increased possibility of the operator becoming distracted with trying to navigate a vessel. A rental vessel is also twice as likely to be involved in an accident versus a non-injury vessel, possibly due to operator inexperience.

4.3 Contributing Factors to deaths in Florida recreational boating accidents

This final logistic regression explained in Table 7 looks at boating accident fatalities in Florida during 2018. The same variables for the injury model were utilized, regressing on the dependent variable that either a fatality did or did not occur in a boating accident.

[24] Non-propelled vessels in this study include canoes, pontoon boats, stand up paddleboards, kayaks and rowboats

Table 7 – Logistic Regression Output for Fatalities from 2018 Florida Boat Accidents

Variable	Coefficient	Standard Error	Exponent	Odds Ratio	Standard Error	p-value	Significant
Constant	-2.227	1.436	4.961	0.108	0.155	0.121	
Age	0.013	0.010	0.000	1.014	0.010	0.162	
Day	-0.620	0.340	0.384	0.538	0.183	0.068	
Power-Driven Vessel	-0.803	0.414	0.645	0.448	0.185	0.052	
Rental Vessel	-1.178	0.659	1.388	0.308	0.203	0.074	
Weekend	-0.365	0.302	0.133	0.694	0.209	0.226	
Operator Education	-0.945	0.459	0.894	0.389	0.178	0.039	Yes
Weather							
Clear	0.875	0.733	0.766	2.400	1.758	0.232	
Cloudy	0.815	0.689	0.665	2.260	1.557	0.237	
Rain	0.238	0.669	0.057	1.269	0.849	0.722	
Hazy	1.204	1.239	1.450	3.334	4.131	0.331	
Operator Experience							
< 10 hours	-0.758	0.654	0.574	0.469	0.306	0.246	
10 - 100 hours	-1.502	0.552	2.257	0.223	0.123	0.006	Yes
101 - 500 hours	-0.912	0.451	0.832	0.402	0.181	0.043	Yes
Water Condition							
Choppy	0.277	0.385	0.077	1.319	0.507	0.472	
Rough	0.007	0.668	0.000	1.007	0.673	0.992	
Very Rough	0.000	(empty)	0.000	1.000	(empty)		
Wind Condition							
Light	1.058	1.083	1.119	2.880	3.117	0.329	
Moderate	0.640	1.112	0.410	1.897	2.110	0.565	
Strong	1.023	1.175	1.047	2.782	3.268	0.384	
Storm	0.000	(empty)	0.000	1.000	(empty)		

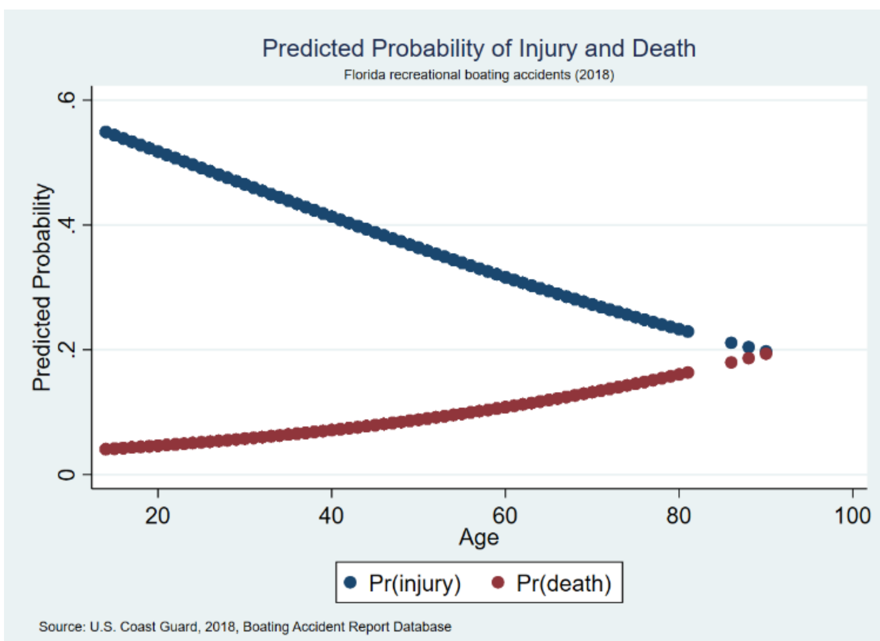
Log-Likelihood = -174.279 | n = 639| df = 18 | LR chi-square = 40.35 | Pseudo R^2 = .1037

The results did not find any environmental, time or operator variables to be statistically significant. In evaluating our hypothesis (1), since age is not a statistically significant variable, we fail to reject the null hypothesis. However, if we apply this same hypothesis to operator education or experience, we can reject the null hypothesis in favor of the alternative hypothesis that there is a relationship between these two variables and fatality in a boating accident.

This model does find operator education and experience to be statistically significant in reducing the odds of a fatality. For instance, an operator having a boating education is 62% less likely to sustain a fatality in a boating accident. For boater experience, an operator having 101 – 500 hours of experience was 60% less likely to sustain a fatality in a boating accident. These were interpreted utilizing the odds ratio for each variable, with the aforementioned all being less than one, indicating a negative relationship.

Finally, Figure 2 incorporates the operator age variable from both models and plots out their respective predicted probability in both injury and fatality (death) as a result of a boating accident. In the case of injuries, the plot shows the negative correlation between age and injury. When evaluating fatality, the plot shows the positive correlation between age and death.

Figure 2 – Predicted Probability of Injury and Death in 2018 Florida Boating Accidents



5.0 Conclusion

This study aims to utilize data collected by different sources in order to illustrate the recreational boating environment and better define the recreational boating safety culture. Current scholarly research focuses on accident data alone or utilizes survey-based methodologies to collect data from boaters. Currently research on public regulation in recreational boating also evaluates the relationship of broad-level regulation on boating accidents. This study combines Federal and State data and evaluates boating safety from the county level for the State of Florida in 2018. This study also utilizes accident-level data to determine the relationship between boater education and injury or death in a boating accident. This methodology can be applied to any U.S. State, or to nationwide data. This was accomplished by looking at the data two ways.

First, data was collected from five different sources for each Florida county encompassing both Federal and State level governance. Then the relationship was evaluated four different ways to evaluate which variables had relationships with the independent variable: boating accidents. When evaluated together, demographic, access and safety variables had a different effect evaluated together rather than separately. The model found that the number of marinas had a positive correlation with boating accident numbers. The model also found that the number of boating safety zones had a negative correlation with county boating accident numbers. The model also found some astonishing results in that number of boater safety cards and number of aids to navigation all had a positive correlation with the number of accidents. This could be interpreted as, the higher the number of each aids to navigation and issuances of boater safety identification cards contributed to more accidents. Utilizing this methodology presents a challenge in a public sector setting in that the result is opposite of what is expected. More research is recommended for the effects of aids to navigation and boating safety zones and their impacts on boat traffic and accidents.

Second, an analysis of accident-level data was made utilizing logistic regression. The findings indicate a difference in interaction of variables between injuries and fatalities sustained in a boating accident. In the case of injuries, several variables were found to be significant such as age, accident occurring during the day or night, whether the vessel involved was power-driven and whether the vessel was rented. In accidents involving a fatality, only education and experience were found to have a negative relationship with fatalities, meaning that one with education or experience would reduce their probability of death in a boating accident.

What does this mean for boating safety identification cards in Florida? When looking at card issuance at the county level, the models in this research suggested a negative correlation. This means that an increased number of safety identification cards translated to an increase in boating accidents. A result like this may not bode well for performance-based budgeting. However, when the studies looked at accidents at the accident-level, it found that operator education had a relationship with reducing boating fatality in a boating accident.

5.1 Challenges and Potential

The challenge with examining aggregated county data is the accidents that occurred in that particular county may not have even interacted with variables being reviewed. For instance, an accident may have occurred at the dock when a boater was trying to moor or a vessel could have caught fire due to a mechanical issue and caused injury or a fatality. However, the strength of examining a county at the aggregate level is being able to gauge how the collection of variables that are universal to all counties and waterways throughout the country interact. This leads to a potential for a nationwide study utilizing the same variables and methodology. This could also lead to a study on the availability of similar data sets and statistics by state and its respective counties.

Any aspect of this study can be taken and expanded upon as well. For instance, there has been research ranging from boater safety zones to the epidemiology of recreational boating fatalities. The initial idea of this project was to evaluate recreational boating accidents against channel markers and aids to navigation. Initial analysis indicated that there were a handful of incidents a year that met the criteria. A decision was made to pivot the research and look the public policy implications of boater safety education, which is a state regulation. The accident-level methodology and aggregated county methodology are both foundations for further research into the researcher's original topic of aids to navigation strikes. There is also a potential and a need to look at the effect of aids to navigation on marine casualties, especially when the data at the county level show an unexpected correlation.

One other challenge related to the study of recreational boating is the lack of available data. The total number of registered boaters in a county is a known, but these boaters may drive to other counties to launch their boats. Therefore, it is important to seek information at the waterway level on activity in order to form a baseline of usage. However, that data is limited to survey research data where respondents answer questions. There are other gauges such as counting traffic at landmarks, counting the number of boats that pass under bridges or utilizing sensor data. One caveat of sensor data is that recreational boats typically are not required to carry sensors, thus limiting available data to larger boats and yachts that do require it. There have been advances in traffic counting of vehicles and bicycles, and recreational boating agencies may be able to adopt some of those techniques. Further, research such as this study will help boat insurance companies measure risk and derive factors in which to rate boaters. This can also translate to Federal and State officials with responsibility for maintaining waterways educating themselves more about their areas of responsibility and better learn their domain.

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Curriculum Vita

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